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### ABSTRACT

A redesign of the initial (Group I) Block V module was done and documented. Manufacturing experience and accelerated test data from Group I formed the basis for the redesign. Ten Block V Group II modules were submitted for evaluation and the results are presented.

## 1. SUMMARY

The objective of this contract is to redesign and document Mobil Solar's Block V module. A previous contract documented and submitted 10 modules of the initial (Group I) design. Manufacturing experience, technical innovations and accelerated test results served as the basis for the redesign (Group II).

Several problems existed with the initial design. Among them were delamination of the backskin, power loss due to cracked cells, Hipot failure, oxidation of electrical hardware and weather seal integrity. Solutions to many of the problems were identified, even prior to the completion of the Group I modules. A new backskin eliminates delamination, plastic molded J-boxes and non-conductive gasketing corrected the Hipot failures, redundant interconnects stop power loss due to cracked cells and tinned electrical hardware prevent oxidation. The weather seal integrity is still a problem because of the -50 psf mechanical loading. Lifting of the two short module edges from the roof structure occurs at this loading and breaks the weather seal. It is felt that  $\pm 20$  psf is a more appropriate loading level for residential applications.

The manufacturing experience was excellent with the Group II modules. The design changes were incorporated smoothly and helped simplify the assembly.

Accelerated testing showed only two design areas which are questionable. Both involve the roof structure's ability to withstand the temperature cycling and mechanical loading. At 90°C during the temperature cycling, the PVC drip troughs softened and allowed the module to shift slightly and the negative 50 psf mechanical load violated the weather seal at the short ends of the module. Solutions can be found to both of these problems; however, since it is extremely unlikely that either of these two conditions would ever occur in a real installation, it would only be adding an unnecessary expense.

Delays in obtaining Group I test results and manufacturing the Group II modules have extended this contract seven months.

Additional work may be warranted to investigate the grounding of the backskin foil or removal of it and to evaluate realistic accelerated tests for integral mount roof structures.

## 2. INTRODUCTION

Mobil Solar's approach to residential photovoltaics is to provide a low cost module and installation method for the system owner. EFG ribbon solar cells assembled in large area modules integrally mounted to the roof can reduce the system cost substantially. Several installations have been completed and are functioning well using these modules and very similar mounting methods.

The basic design of the Block V modules has remained the same for both Group I and Group II. Shortcomings of the Group I modules were detected early and solutions were well underway at the completion of the modules. The Group II modules and mounting system offer reliability, simplicity, potential low cost and aesthetic appeal.

## 3. MODULE DESIGN

### 3.1. GENERAL DESCRIPTION (Figures 1, 2, and 3)

The module construction typifies current laminated construction technology. Tempered low iron glass is used as the superstrate and load bearing member. The cell array is laminated to the glass using EVA. The back side of the array is encapsulated with a second layer of EVA and the final weather barrier is a composite laminate. All power buses are run internal to the module and exit the backskin directly into the junction box. The cell array consists of 432 EFG ribbon solar cells, interconnected with redundant copper tabs into an array of 12 parallel by 36 series. Cross ties are provided every 12 cells.

### 3.2. SOLAR CELL (Figure 4)

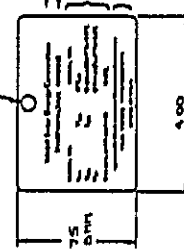
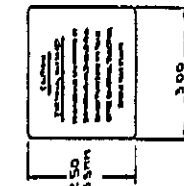
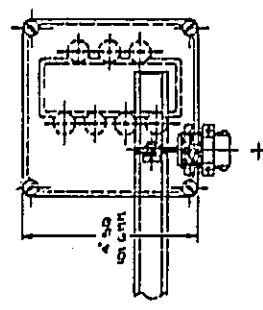
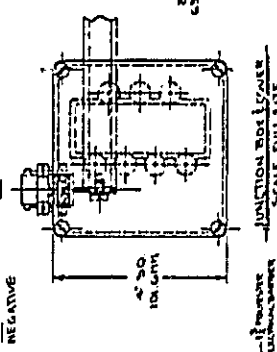
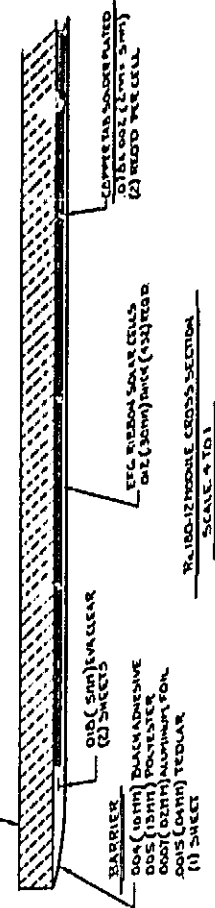
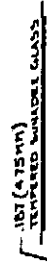
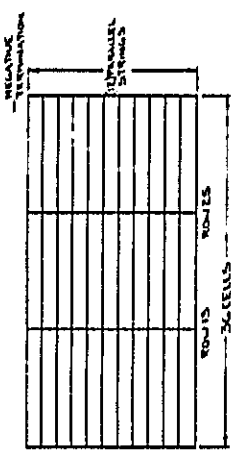
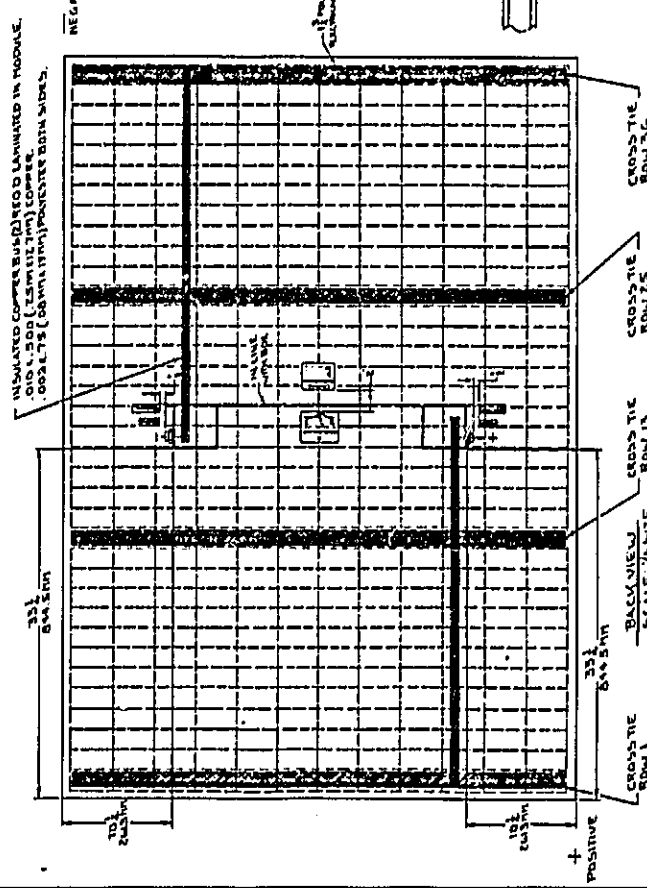
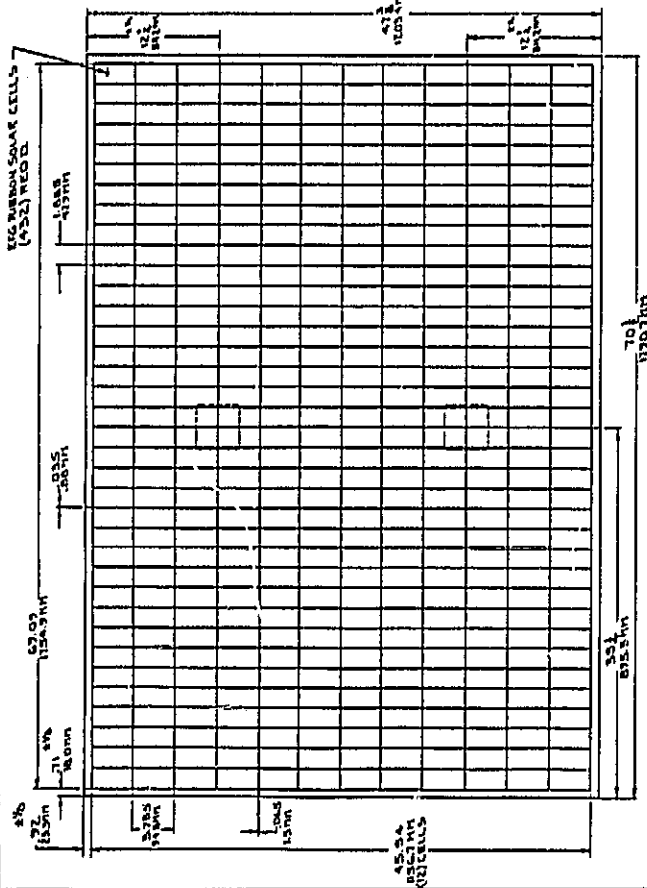
The solar cells are made from silicon EFG (Edge Defined-Film Fed-Growth) ribbon. The junction is N+ on P and the metallization system is a base metal plating. A solder coating facilitates bonding between cell and interconnect. Nominal dimensions are 3.735 x 1.885 x 0.012 in.

### 3.3. INTERCONNECTS/WIRING

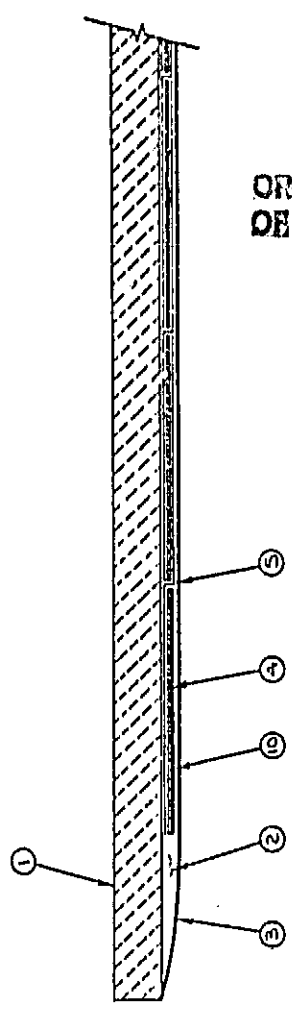
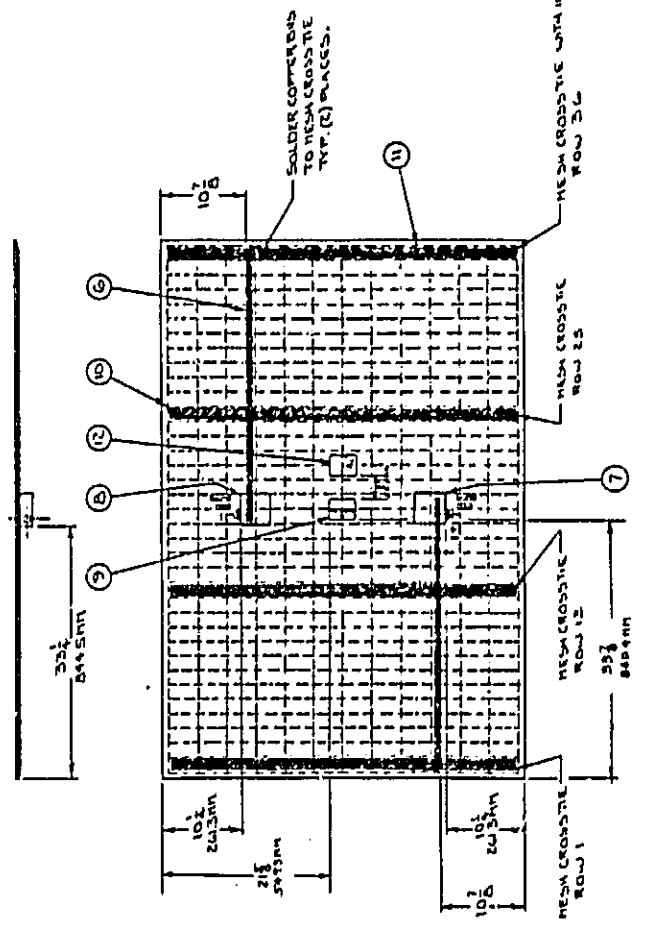
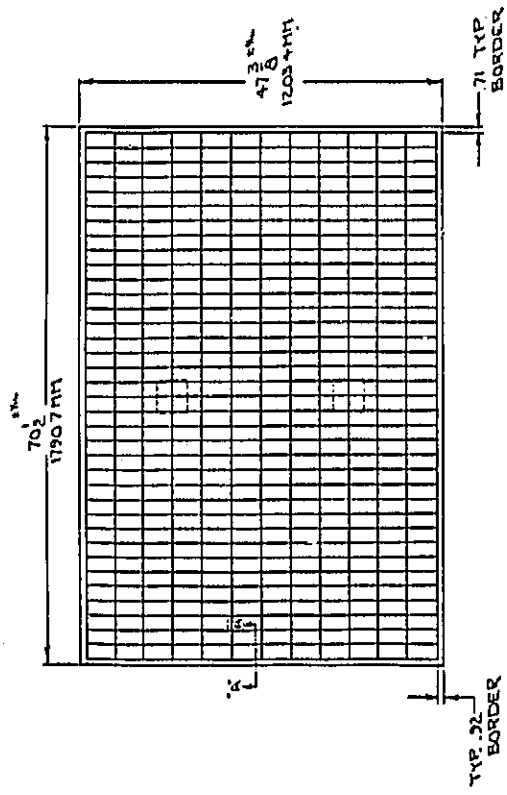
Solder plated copper straps are reflowed soldered across the entire front and back of each cell. Two 0.078 in. x 0.002 in. straps are used per cell which provide redundancy in the event of cell breakage. String cross ties are a solder plated copper mesh. The mesh also serves as a transition between the cell interconnects and the insulated copper power bus.



**Notes**

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1. Name of company 2. Address 3. City 4. State 5. Zip 6. Telephone 7. Fax 8. E-mail 9. Website 10. Name of contact person 11. Title 12. Department 13. Division 14. Branch 15. Office 16. Room 17. Box 18. Suite 19. Floor 20. Building 21. Postal code 22. Country 23. Continent 24. Region 25. Sub-region 26. District 27. Sub-district 28. Ward 29. Sub-ward 30. Village 31. Sub-village 32. Hamlet 33. Sub-hamlet 34. Settlement 35. Sub-settlement 36. Locality 37. Sub-locality 38. Place 39. Sub-place 40. Spot 41. Sub-spot 42. Point 43. Sub-point 44. Location 45. Sub-location 46. Site 47. Sub-site 48. Place 49. Sub-place 50. Spot 51. Sub-spot 52. Point 53. Sub-point 54. Location 55. Sub-location 56. Site 57. Sub-site 58. Place 59. Sub-place 60. Spot 61. Sub-spot 62. Point 63. Sub-point 64. Location 65. Sub-location 66. Site 67. Sub-site 68. Place 69. Sub-place 70. Spot 71. Sub-spot 72. Point 73. Sub-point 74. Location 75. Sub-location 76. Site 77. Sub-site 78. Place 79. Sub-place 80. Spot 81. 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SECTION A-A  
 SCALE: 4 TO 1

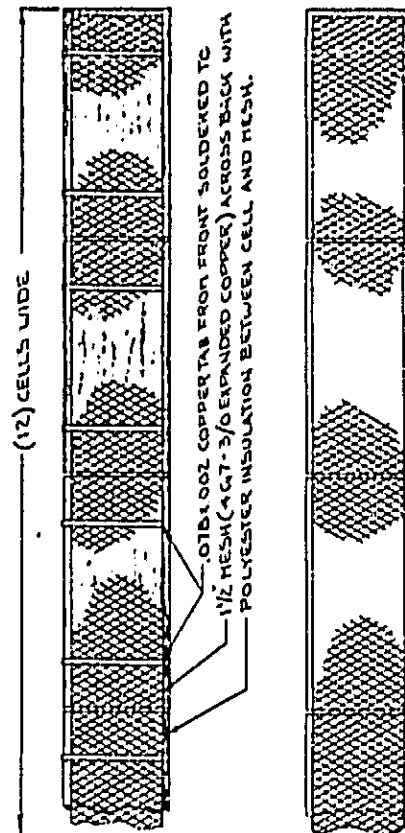
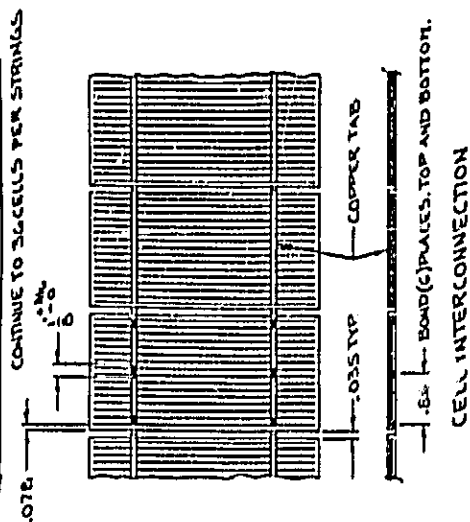
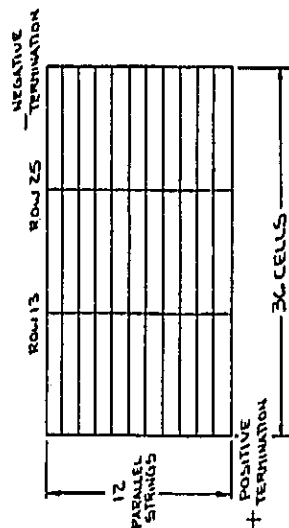
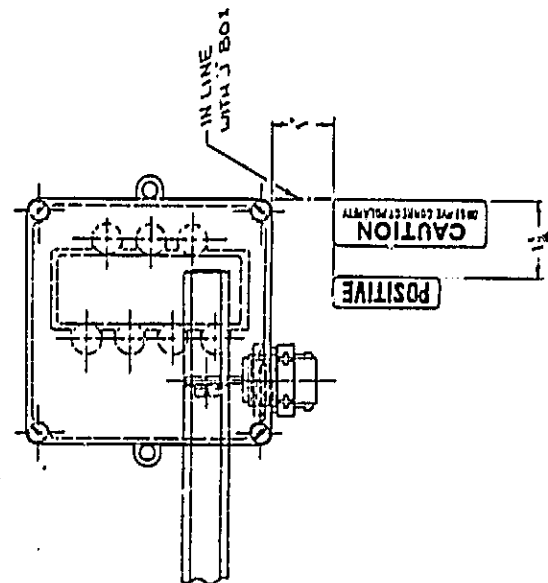
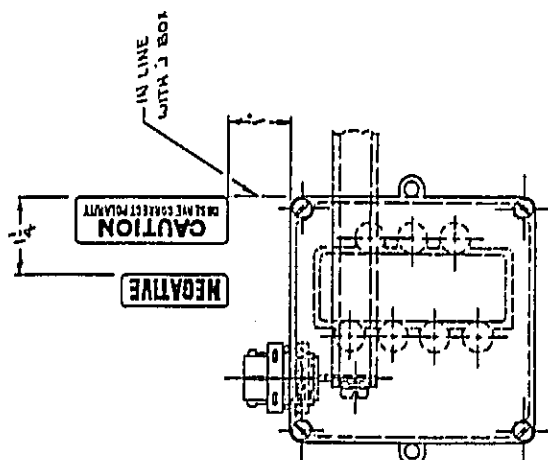
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ITEM	QTY	DRAWING NO.	DESCRIPTION
1	1	B2005049	WARNING LABEL
2	1	B2005051	INSULATION TAPE
3	1	B2005040	MESH CROSS-TIE
4	1	B2005032	MODULE LABEL
5	1	C2005052	JUNCTION BOX ASSEMBLY NEGATIVE
6	1	C2005051	JUNCTION BOX ASSEMBLY POSITIVE
7	1	B2005040	POWER BUS ASSEMBLY
8	1	B2005032	INTERCONNECT
9	1	D2005030	REF. SOLAR CELL
10	1	C2005040	WEATHER BARRIER
11	1	C2005037	ENCAPSULANT
12	1	C2005030	MODULE SUBSTRATE

THESE DRAWINGS SPECIFY THE DESIGN OF THE SOLAR MODULE ASSEMBLY. THE SOLAR MODULE ASSEMBLY SHALL BE MANUFACTURED IN ACCORDANCE WITH THE SPECIFICATIONS AND REQUIREMENTS OF THE SOLAR MODULE ASSEMBLY. THE SOLAR MODULE ASSEMBLY SHALL BE MANUFACTURED IN ACCORDANCE WITH THE SPECIFICATIONS AND REQUIREMENTS OF THE SOLAR MODULE ASSEMBLY.

Model Type: Solar Energy Corporation  
 ASSEMBLY DRAWING  
 14180-12 MODULE

DATE: 10/25/82  
 DRAWN BY: J. C. JONES  
 CHECKED BY: J. C. JONES

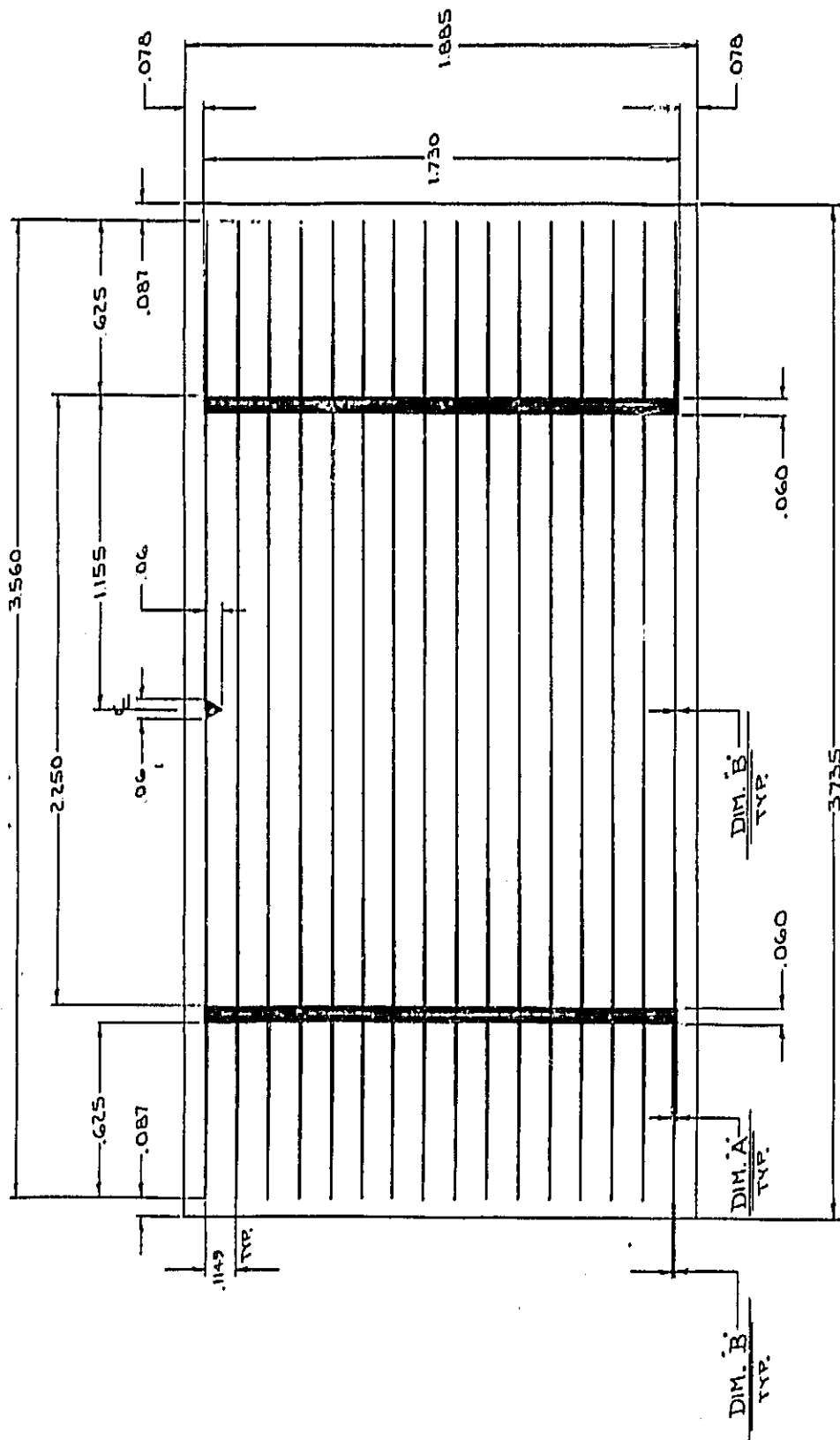


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STRING INTERCONNECTION AND  
CROSS TIE BACK VIEW

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Two junction boxes (one positive and one negative) are adhesively bonded to the back of the module using a silicone RTV. Each power lead enters the J-box through a slot in the bottom of the box and is screwed to the tongue on the bulk head connector. Interconnection of modules is done by plugging them together with male harnesses.

#### 3.4. SUPERSTRATE

Tempered low iron glass was selected as both the structural support and front cover of the module. Light transmission, reliability, cost and compatibility to the lamination process were all factors which made glass the preferred choice. The glass length and width (70-1/2" x 47-3/8") are also the dimensions of the module because it is frameless. The thickness is 3/16". Structurally, 1/8" glass would be adequate; however, sagging of the glass when mounted may be an aesthetic problem.

The glass is prepared for lamination with a wash and subsequent priming of the inside surface.

#### 3.5. POTTANT

Modified commercially available Ethylene Vinyl Acetate (EVA) using standard lamination techniques was chosen as the encapsulation system. The manufacturer's experience with EVA and its proven laboratory performance made it the preferred choice of encapsulants.

#### 3.6. WEATHER BARRIER

A multi-layer laminate of Tedlar, Al foil, polyester and adhesive serves as a final weather barrier. Tedlar is widely used in the industry as the outer skin because of its proven reliability. Aluminum foil is included as the primary vapor barrier offering corrosion protection to the cells and interconnects. A film of polyester serves as an electrical insulator between the aluminum foil and cell array. Finally, an opaque adhesive bonds the composite weather barrier to the EVA during the lamination cycle.

#### 3.7. EDGE SEAL/INSULATION

No special provisions are made for edge sealing the module other than bringing the weather barrier tightly to the glass edge during lamination. The polyester film inside the weather barrier works well as an insulator; however, since the module is frameless, there is no provision for externally grounding the foil to an array support structure.

### 3.8. ROOF MOUNTING (Figures 5 and 6)

The module has been designed to be roof integrated; therefore, no self-contained framework exists with the module. The module width is slightly less than 4 ft. which fits with rafter spacings of 16 in. on center. The J-boxes are located such that no interference will exist with framing members.

The mounting system utilizes the rough framing of the dwelling roof as the frame and mechanical support for the module. The module is secured to the rafters with a screw-down batten which runs the length of each side of the module and clamps it to the rafter. Purlins support the module ends from underneath, but there is no batten on top. Debris, rain, snow, etc., are free to slide off the module face without catching on horizontal lips.

Non-conductive gasketing is used around the perimeter of the module as a weather seal and cushion; however, in the event of a leak, drip troughs installed directly over the rafters and purlins will channel water harmlessly to the outside. A silicone RTV is used across the top and bottom of the module as a seal between modules.

It is recommended that louvers run continuously along the top and bottom of the array for proper ventilation.

### 4. MODULE NOMINAL ELECTRICAL PERFORMANCE

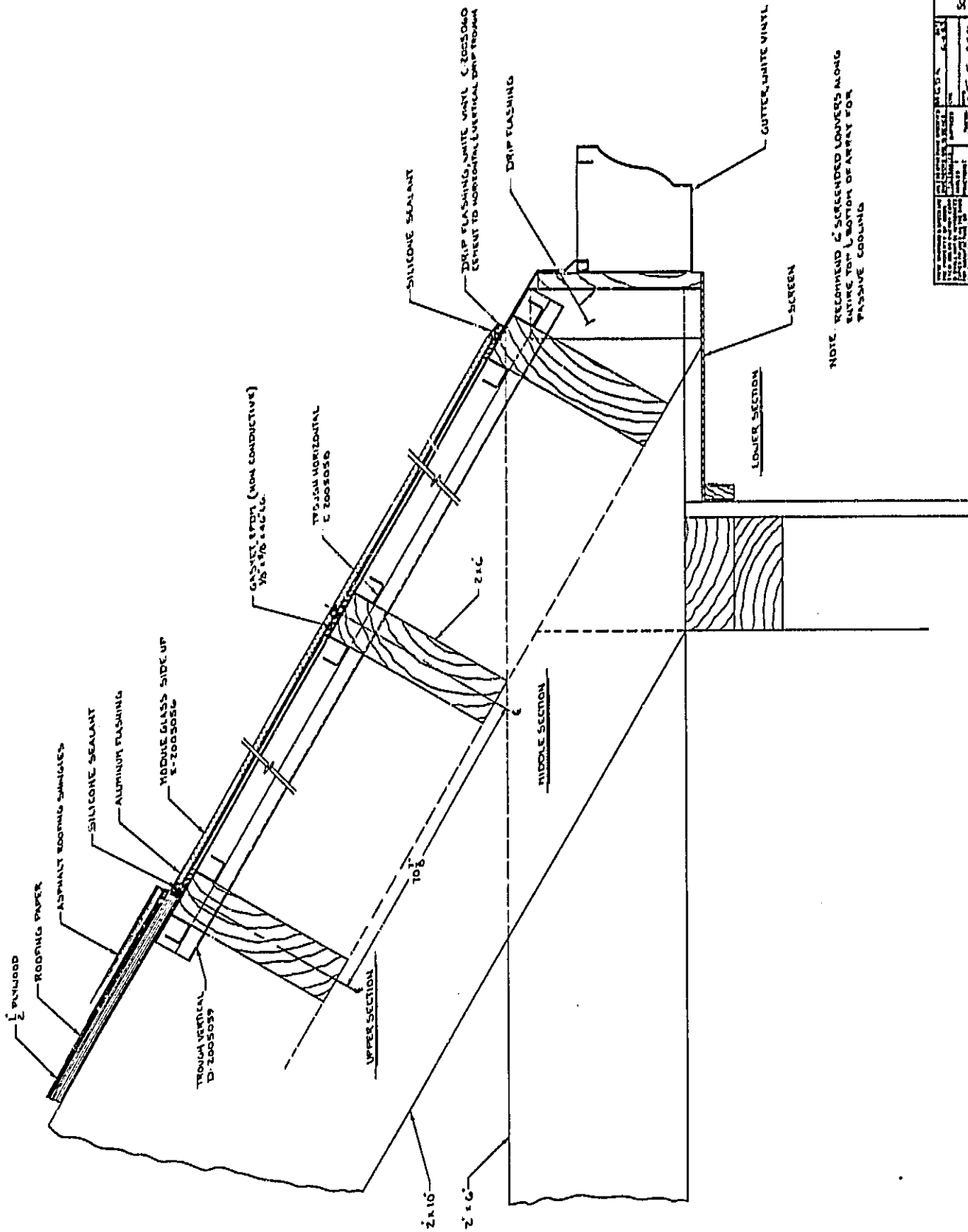
Listed in Table 1 is the nominal performance for two operating conditions for the Group II module.

Table 1. Nominal Group II Module Performance.

Parameter	80 mw/cm <sup>2</sup>	100 mw/cm <sup>2</sup>
	NOCT AM1.5	NOCT AM1.5
Peak Power	128.8 W	158.5 W
Voltage, Open Circuit	17.04 V	16.78 V
Current, Short Circuit	10.91 a	13.69 a
$\eta_m$ , module efficiency*	7.4%	7.2%
$\eta_c$ , encap. cell efficiency**	8.2%	8.1%
PF, Packing Factor	89.4%	89.4%
FF, Fill Factor	0.693	0.690
NOCT	46°C	51.5°C
$V/T = .012$ v/°C		
$I/T = .078$ a/°C		

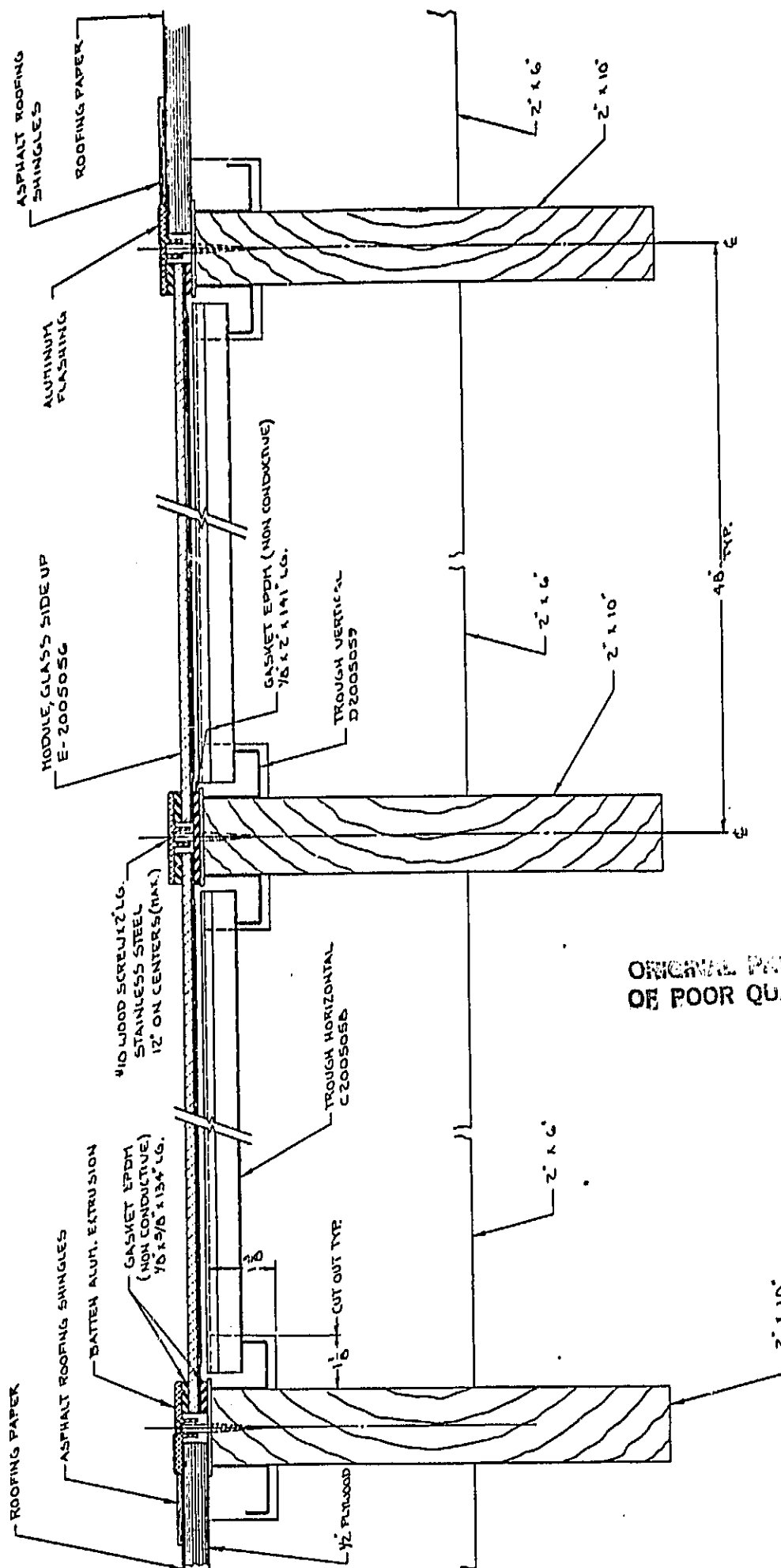
\* As mounted in an array. 48" x 70<sup>7</sup>/<sub>8</sub>" on center dimensions.

\*\* Using nominal cell dimensions.



Mtd Jcd		Soc Energy Corporation		EAST WEST VIEW		2005062		2005062	
Soc Energy Corporation		EAST WEST VIEW		2005062		2005062		2005062	
Soc Energy Corporation		EAST WEST VIEW		2005062		2005062		2005062	
Soc Energy Corporation		EAST WEST VIEW		2005062		2005062		2005062	
Soc Energy Corporation		EAST WEST VIEW		2005062		2005062		2005062	
Soc Energy Corporation		EAST WEST VIEW		2005062		2005062		2005062	
Soc Energy Corporation		EAST WEST VIEW		2005062		2005062		2005062	
Soc Energy Corporation		EAST WEST VIEW		2005062		2005062		2005062	
Soc Energy Corporation		EAST WEST VIEW		2005062		2005062		2005062	
Soc Energy Corporation		EAST WEST VIEW		2005062		2005062		2005062	

FIGURE 5



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<b>Model 1100</b> <b>Solar Energy Corporation</b>		DATE: <u>10/1/81</u> DRAWN BY: <u>W. J. B.</u> CHECKED BY: <u>W. J. B.</u>
<b>INTEGRAL MOUNTING</b> <b>NORTH-SOUTH VIEW</b>		SCALE: <u>1/4" = 1'-0"</u> SHEET: <u>1</u> OF <u>1</u>
THIS DRAWING SPECIFICALLY REFERS TO THE FOLLOWING SPECIFICATIONS:		MATERIALS: ALUMINUM: <u>6061-T6</u> GLASS: <u>1/4" THICK</u> EPDM: <u>1/8" THICK</u> STEEL: <u>1/2" THICK</u> PLYWOOD: <u>1/2" THICK</u> ASPHALT: <u>30 YEAR</u> ROOFING: <u>SHINGLES</u>
THESE DIMENSIONS ARE BASED ON THE FOLLOWING ASSUMPTIONS:		1. ALL DIMENSIONS ARE IN INCHES 2. ALL DIMENSIONS ARE TO FACE 3. ALL DIMENSIONS ARE TO CENTER 4. ALL DIMENSIONS ARE TO EDGE 5. ALL DIMENSIONS ARE TO SURFACE 6. ALL DIMENSIONS ARE TO CENTER 7. ALL DIMENSIONS ARE TO FACE 8. ALL DIMENSIONS ARE TO CENTER 9. ALL DIMENSIONS ARE TO FACE 10. ALL DIMENSIONS ARE TO CENTER



The above performance data was generated from both individual cell characteristics and actual module data. Shown below in Table 2 is a sampling of typical large area module performance. These modules are a nominal 24V rather than 12V for the Group II modules.

Table 2. Typical Large Area Module Performance.

MODEL	N	PP (W)	VOC (V)	ISC (A)	IP (A)	VP (V)	ITEST (A)	FF	POWER PFV PP (KW)
180-24D X	21	181.79	38.29	6.30	5.71	31.87	5.639	0.753	3.672
S		4.98	0.35	0.17	0.20	0.59	0.16	0.016	3.818

## 5. BLOCK V QUALIFICATION TESTS

### 5.1. TEST PROCEDURES

The module qualification tests are the standard Block V series as outlined in the JPL document 5101-162 "Block V Solar Cell Module Design and Test Specification for Residential Applications - 1981". They are listed below and further details may be found in JPL document 5101-163, "Block V Solar Cell Module Design and Test Specification for Residential Applications-1981".

- Thermal cycle: 200 cycles, -40 to 90°C.
- Temperature-humidity: 10 cycles, 85°F/85% RH with a -40°C plunge every 24 hrs.
- Hail impact
- Mechanical loading: 10,000 cycles, ±50 psf.
- Twisted mount
- Hot spot heating
- Hi potential: ±3000 VDC

### 5.2. BLOCK V, GROUP I MODULE TEST RESULTS

The Group I module was the first Mobil Solar design of a roof integrated Block V module. Several significant changes were made to the Group II module as a result of processing experience and Block V qualification tests. The results are as follows:

#### 5.2.1. THERMAL CYCLING

One module of the six cycled (4 for 50 cycles and 2 for 200 cycles) failed due to electrical performance after 50 cycles. Probable cause is broken cells. Non-redundancy of the interconnect system makes the module susceptible to this failure mode.

Thermal cycling aggravated back skin delamination, which existed initially in some modules. Poor adhesion between the polyester insulation layer and EVA caused the problem.

No interconnect fatigue was noted after all cycling was complete.

#### 5.2.2. HI POTENTIAL/CONTINUITY

Initial hipot tests produced failures in all modules. Several factors contributed to this. The backskin foil was not grounded to the metallic drip troughs, the gasketing material was electrically conductive, and the junction box is metallic. Subsequent testing before and after other stress tests resulted in eventual passage.

#### 5.2.3. HUMIDITY FREEZE

The humidity freeze caused more delamination of the backskin and the one module which degraded electrically after thermal cycling continued to degrade. Oxidation of the hardware inside the J- box began to occur.

#### 5.2.4. MECHANICAL LOADING

Two modules of four showed separation of sealant from the module edge at the two short ends. These two edges are not securely fastened to the roof structure and during the -50 psf loading the module edge is lifted up breaking the seal. In addition, in one of the two modules, three of the five wood screws used to secure the bottom to the rafter pulled out. Some additional backskin delamination was observed.

#### 5.2.5. TWISTED MOUNT, HOTSPOT, FINAL HI POTENTIAL

Performance was satisfactory.

### 5.3. BLOCK V, GROUP II MODULE TEST RESULTS

The Group II modules passed the Block V qualification tests. Their were some changes to the module as a result of the tests, however, they were minor. The suggested mounting system did not pass the qualification tests. Thermal cycling produced module movement and distortion of mounting materials. The results of each test are as follows:

#### 5.3.1 ACTUAL MODULE ELECTRICAL PERFORMANCE

Shown in Table 3 are the actual average electrical parameters as measured at JPL upon receipt.

Table 3 - Actual Group II Module Performance

No. Modules	100 mW/cm <sup>2</sup>		25°C		AM 1.5	
	PP (W)	Voc (V)	Isc (A)	IP (A)	VP (V)	FF
10	177.1	18.94	12.92	11.73	15.09	.723

#### 5.3.2 THERMAL CYCLING

Fifty thermal cycles produced no changes to the modules. Two hundred cycles showed fatigue stress marks on 20% of the interconnects but no cracking. Average power degradation after all cycling was -.2% with no module more than -2.4%.

Problems occurred during the first fifty cycles with the simulated vinyl drip troughs. The vinyl had softened at the high temperature causing the module to slide in the framework. Continued thermal cycling caused distortion of the vinyl.

#### 5.3.3 HI POTENTIAL/CONTINUITY

There were no hi potential test failures and by design, no continuity.

#### 5.3.4 HUMIDITY FREEZE

This test was satisfactory, however, one module showed a group of small bubbles at one spot in the module. There is no explanation for this.

Power measurements of the four modules showed a consistent 3-3.1% loss for three of the modules and one at +1.5%. The tight consistency of the three was either a very peculiar coincidence or some unexplained phenomena occurred. Two of the three recovered half of the loss in subsequent tests.

#### 5.3.5 MECHANICAL LOADING

Two of the three modules showed cell cracking after testing, but it had no affect on performance. The cracks may have existed before testing and were aggravated during the test to the point of becoming visible.

#### 5.3.6 TWISTED MOUNT, HOTSPOT, FINAL HI POTENTIAL

Performance was satisfactory.

## 6.0. MODULE DESIGN CHANGES

No changes to the module design are warranted as a result of the qualification tests. The cell cracking noticed after mechanical loading is probably best corrected by reducing cracked cells at or prior to encapsulation.

Improvement to the support structure is needed to pass the qualification tests. The major problem was the inability of the simulated vinyl drip troughs to survive the 90 °C temperature. The selection of a higher temperature plastic should correct the problem.

## 7.0. CONCLUSIONS AND RECOMMENDATIONS

Significant improvements were made in the module design between Group I and Group II.

Replacement of the adhesive system used in bonding the backskin to the EVA eliminated the serious delamination seen with Group I modules. The incorporation of redundant interconnects with Group II modules reduced power losses to less than 2-3% even with a significant number of visibly cracked cells. The change from conductive to non-conductive gasketing, drip troughs and junction boxes corrected the many hi potential failures. These three major changes lead to the successful completion of the Block V qualification tests.

No changes to the module design is recommended. A material substitution for the drip troughs is necessary for the recommended mounting system to pass, however, it is the opinion of MSEC that both the mechanical loading and thermal cycling tests are too severe for an integrated residential roof mounting system. Given realistic tests ( $\pm 20$  psf mechanical loading; -20 to + 60 °C thermal cycling) the current system is satisfactory.

APPENDIX 1

SUMMARY RESULTS OF ENVIRONMENTAL TESTS  
OF SOLAR MODULES AT JPL

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GROUP I AND GROUP II MODULES

Revision dates  
9/2/83

9/27/83  
11/30/83  
02/13/84  
02/22/84

App'd.  
*[Signature]*  
*[Signature]*  
*[Signature]*  
*[Signature]*

SUMMA.

Results of Environmental Tests  
of Solar Modules at JPL

GROUP I

Prepared by: F. Erren  
Approved by: *[Signature]*  
Date: 7/28/83  
Rev. 8/15/83  
Rev. 8/24/83

Vendor	Module S/Ns	Module Type	Test	Electrical Degrad., %	Comments
MSEC Gr 1 LS5H	3493, 3550, 3551, 3554 (simulated roof sections)	RA-160-12	Hipot/ Continuity		Initially failed hipot & continuity in vendor-built roof section. After several tests were made, module would eventually withstand the 1500V hipot requirement. Rubber gasket is electrically conductive. Roof not designed for continuity test (metal troughs, j-boxes not connected.) Cell string to j-box short, S/N 3551.
	3493, 3550, 3554, 3555		Hipot/ Continuity		Modules mounted in simulated roof installation assembled from vendor-supplied materials. Again failed initial hipot & continuity tests.
	3509, 3567		T-50v	--	Back surface delaminated over a substantial area in one corner, S/N 3509.
	3493, 3550, 3554, 3555		T-50v	-9.7% S/N 3550	Electrical failure, 1 mdl. Five of six modules show back surface delam with 10 x 15 cm spots common.
	3509, 3567		T-200v		Satisfactory. No Interconnect fatigue noted.
	3493, 3550 3554, 3555		HF-10	-11.7 S/N 3550	Resistance to ground dropped to less than 1 Mohm, 4 mdls. More delamination front and back. J-box hardware oxidized, S/N 3550.
	3493, 3550, 3554, 3555		M-10K		Modules had 1, 1, 5, and 6 cells cracked, resp. Glass separated from sealant at ends of 2 modules. S/N 3493 had 3 of 5 screws pulled out of the wooden rafters, one side. S/N 3550 had a 5 X 10 cm area of Tedlar delaminated.
			Twist		Satisfactory.
			Hail-1.0		Satisfactory.
	3493, 3550 3554, 3555		Hipot, Cont'ty		Hipot satisfactory. No continuity by design.
	3558		HS-100		Satisfactory. Testing completed on these modules.

# F S A M O D U L E T E S T S U M M A R Y

TEST SPEC 5101-161,162 (100mW/sq cm)

TEST-DURATION  
HF = Humidity Freeze-Cycles  
HS = Hot Spot-Cycles  
HL = Hall-Size/Inches  
M = Mech Integrity-Cycles  
S/A = Mounted in Subarray  
T = Temperature-Cycles

LETTERS = Mfrer/Block/Use  
Number = Vendor Serial No.

COEFF = Temp Coefficient  
DELAM = Delamination  
DSCN = Discoloration  
ENCAP = Encapsulation  
INITCON = Interconnector

COMMENTS  
DPMX = Delta PMAX of Control Module  
I = Identifier: J = JPL, V = Vendor  
P/FR = Failure Report No.  
SAT = Tested Satisfactorily  
SBSTR = Substrate

DELTA, PCT = Difference Percent  
FF = Fill Factor, PM/ISC X Voc  
FLASH DATE = Date of Elec Test

DELTA, PCT = Difference Percent  
FF = Fill Factor, PM/ISC X Voc  
FLASH DATE = Date of Elec Test

DELTA, PCT = Difference Percent  
FF = Fill Factor, PM/ISC X Voc  
FLASH DATE = Date of Elec Test

DELTA, PCT = Difference Percent  
FF = Fill Factor, PM/ISC X Voc  
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DELTA, PCT = Difference Percent  
FF = Fill Factor, PM/ISC X Voc  
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DELTA, PCT = Difference Percent  
FF = Fill Factor, PM/ISC X Voc  
FLASH DATE = Date of Elec Test

DELTA, PCT = Difference Percent  
FF = Fill Factor, PM/ISC X Voc  
FLASH DATE = Date of Elec Test

LS5H-3509	1	INITIAL	161.40	04/20/83	10.540 23.86 8.350 19.32 .64 3 CELLS CRACKED.	3142
LS5H-3509	2	PRE-TEST	159.91	04/20/83	BASE.	
LS5H-3509	3	T-50	160.45	07/18/83	TEDLAR DELAM 2.5 x .75 cm @ 1 CORNER.	
LS5H-3509	4	T-200	157.66	08/24/83	SATISFACTORY. NO IC FATIGUE.	
LS5C-3547	1	INITIAL	164.25	04/20/83	10.290 23.88 8.550 19.21 .67	
LS5C-3547	2		165.49	04/21/83	CONTROL MODULE. BASE.	
LS5C-3547	3		163.00	07/08/83	CONTROL MODULE.	
LS5C-3547	4		163.60	07/14/83	CONTROL MODULE.	
LS5C-3547	5		162.30	07/18/83	CONTROL MODULE.	
LS5C-3547	6	RECHECK	162.04	07/18/83	CONTROL MODULE.	
LS5C-3547	7		161.47	07/18/83	CONTROL MODULE.	
LS5C-3547	8		161.69	08/03/83	CONTROL MODULE.	
LS5C-3547	9		162.87	08/24/83	CONTROL MODULE.	
LS5C-3547	10		162.38	09/01/83	CONTROL MODULE.	
LS5C-3547	11		162.12	10/19/83	CONTROL MODULE.	
LS5C-3547	12		160.89	10/26/83	CONTROL MODULE.	
LS5C-3547	13		163.76	11/15/83	CONTROL MODULE.	
LS5C-3547	14		162.06	11/16/83	CONTROL MODULE.	
LS5C-3547	15		161.91	12/20/83	CONTROL MODULE.	
LS5C-3547	16		161.57	01/12/84	CONTROL MODULE.	
LS5C-3547	17		163.07	01/24/84	CONTROL MODULE.	
LS5C-3547	18		161.37	02/07/84	CONTROL MODULE.	
LS5C-3547	19		164.77	02/21/84	CONTROL MODULE.	
LS5H-3550	1	HIPOT		05/11/83	FAILED HIPOT (VENDOR ROOF).	
LS5H-3550	2	CONT'TY		05/11/83	FAILED CONT'TY (VENDOR ROOF).	
LS5H-3550	3	HIPOT		06/17/83	FAILED HIPOT (JPL-BUILT FRAME).	
LS5H-3550	4	CONT'TY		06/17/83	FAILED CONT'TY (JPL-BUILT FRAME).	
LS5H-3550	5	RCVG	160.89	07/08/83	10.370 23.70 8.550 18.82 .65	
LS5H-3550	6	PRE-TEST	161.89	07/14/83		
LS5H-3550	7	T-50	146.26	08/03/83	ELEC DEGRAD. BACKSIDE TEDLAR DELAM. 33Mohms RES TO FRAME, ALL HOT CYCLES.	3150
LS5H-3550	8			08/03/83	DEGRAD VERIFIED.	
LS5H-3550	9	RECHECK	146.10	08/03/83		
LS5H-3550	10	RECHECK	146.17	08/03/83		
LS5H-3550	11	HF-10	143.86	08/31/83	497Kohms RES TO GND. HOT END. 1 CELL CR. MORE DELAM 2 SIDES. OXIDATIONS @ J-BOX & SCREWS HOLDING TERM STRIPS.	3098
LS5H-3550	12	RECHECK	142.97	08/31/83		
LS5H-3550	13	HF-10K	141.11	08/31/83	BACKSIDE TEDLAR DELAM 10cm & 5cm @ J-BOX. 1 CELL CRACKED. SEALANT PULLED AWAY FROM GLASS.	3241
LS5H-3550	14			10/19/83	SATISFACTORY THIS TEST.	
LS5H-3550	15			10/26/83		
LS5H-3550	16	TWIST	144.23	10/26/83		
LS5H-3550	17	RECHECK	143.68	11/15/83	SATISFACTORY THIS TEST.	
LS5H-3550	18	HL-1.0	142.93	11/15/83	SATISFACTORY. NO CONT'TY BY DESIGN.	
LS5H-3550	19	HIPOT		11/15/83		
LS5H-3551	1	HIPOT		05/11/83	FAILED HIPOT. CELLS SHORTED TO J-BOX. (VENDOR ROOF).	
LS5H-3551	2	CONT'TY		05/11/83	FAILED CONT'TY.	
LS5H-3551	3	INITIAL	163.69	11/16/83	10.120 23.77 8.440 19.39 .68 NOCT MODULE.	



LS5H-3554	1	HIPOT	05/11/83			FAILED HIPOT (VENDOR ROOF).	
LS5H-3554	2	CONT'TY	05/11/83			FAILED CONT'TY (VENDOR ROOF).	3151
LS5H-3554	3	HIPOT	06/17/83			FAILED HIPOT (JPL-BUILT FRAME).	3250
LS5H-3554	4	CONT'TY	06/17/83			FAILED CONT'TY (JPL-BUILT FRAME).	3175
LS5H-3554	5	RCVG	07/08/83		158.62	9.790 23.82 8.450 18.77 .68	
LS5H-3554	6	PRE-TEST	07/14/83		159.96	BASE.	
LS5H-3554	7	T-50	08/03/83	+0.1	160.06	BACKSIDE TEDLAR DELAM @ NEG END. 33Mohms RES TO FRAME, ALL HOT CYCLES.	
LS5H-3554	8	HF-10	08/31/83	-0.2	159.59	546kohms RES TO GND, HOT ENDS. MORE DELAM FRONT & BACKSIDE.	
LS5H-3554	9	M-10K	11/16/83	-1.0	158.40	5 CELLS CRACKED.	
LS5H-3554	10	TWIST	12/20/83	-2.6	155.86	INSP WAIVED.	
LS5H-3554	11	HL-1.0	01/24/84	-2.8	155.41	SATISFACTORY.	
LS5H-3554	12	HIPOT	01/25/84			SATISFACTORY.	
LS5H-3554	13	CONT'TY	01/25/84			NO CONT'TY BY DESIGN.	
LS5H-3555	1	HIPOT	06/17/83			FAILED HIPOT (JPL-BUILT FRAME).	
LS5H-3555	2	CONT'TY	06/17/83			FAILED CONT'TY (JPL-BUILT FRAME).	3149
LS5H-3555	3	INITIAL	04/20/83		171.80	10.390 23.86 9.150 18.77 .69 1 CELL CRACKED.	3249
LS5H-3555	4	PRE-TEST	04/21/83		170.70	BASE.	3176
LS5H-3555	5	RECHECK	07/08/83		169.81		
LS5H-3555	6	T-50	08/03/83	+1.9	173.91	BACKSIDE TEDLAR DELAM THROUGHOUT. 23Mohms RES TO FRAME, ALL HOT CYCLES.	
LS5H-3555	7	HF-10	08/31/83	+1.9	173.95	344kohms RES TO GND HOT ENDS. MORE DELAM FRONT & BACKSIDE.	
LS5H-3555	8	M-10K	11/16/83	-1.8	167.59	6 CELLS CRACKED.	
LS5H-3555	9	TWIST	12/20/83	-2.4	166.67	SATISFACTORY.	
LS5H-3555	10	HL-1.0	01/24/84	-2.0	167.25	SATISFACTORY.	
LS5H-3555	11	HIPOT	01/26/84			SATISFACTORY.	
LS5H-3555	12	CONT'TY	01/26/84			NO CONT'TY BY DESIGN.	
LS5H-3558	1	INITIAL	04/20/83		158.26	10.140 23.99 8.110 19.52 .65 3 CELLS CRACKED.	
LS5H-3558	2	PRE-TEST	04/21/83		157.99	BASE. HOTSPOT MODULE.	
LS5H-3558	3	HS-100	02/21/84	-1.0	156.48	SATISFACTORY.	
LS5H-3567	1	INITIAL	04/20/83		178.26	10.410 24.12 9.160 19.45 .71	
LS5H-3567	2	PRETEST	04/21/83		178.56	BASE.	
LS5H-3567	3	RECHECK	04/21/83		177.45	SATISFACTORY.	
LS5H-3567	4	T-50	07/18/83	-1.0	175.76	NO IC FATIGUE.	
LS5H-3567	5	T-200	08/24/83	-2.3	173.46		

Revision dates  
7-25-84

8-9-84

9-13-84

10-11-84

App'd.

## SUMMARY

### Results of Environmental Tests of Solar Modules at JPL

#### GROUP II

Prepared by: Frank Ferren  
Approved by: *[Signature]*  
Date: 5-11-84  
Rev. 5-25-84  
Rev. 6-13-84

Vendor	Module S/Ns	Module Type	Test	Electrical Degrad., %	Comments
ISEC B1 V, Ar 2, LS5P	4969, 4971, 4972 4969, 4971 4972, 5001 4976, 5000 4972, 4976 5000, 5001 5083 4969, 4971 4972, 5001 4969, 4971, 4972, 5001	RA-180-12	Hipot/ Cont'y T-50 ~  T-50 ~  T-50 ~  HF-10 ~  HS-100 ~  T-200  H-10K Hipot/ Cont'y	-- --	Initial hipot satisfactory. No continuity by design.  Laminates slid out of end of JPL fabricated wood frames. Frames simulated MSEC design drawings 2005057, -61, -62. Modules were mounted vertically in chamber. Vinyl softened and distorted. Back surface material shrank 3 mm.  Modules in frames were positioned in the chamber on their sides. Laminates slipped downward until stopped by batten screws. White vinyl distorted and shrank(.5 to 1 cm). Silicone sealant was torn from laminate for 7 cm at 2 corner of S/N 4972. Laminate itself was satisfactory.  Modules were tested on their sides. Glass laminate slipped downward, vinyl distorted, silicone sealant torn from laminate at 2 and 3 corners, resp. Slight Tedlar shrinkage.  Silicone roof sealant( N and S ends as mounted on roof) continues to loosen(2 modules). Groups of tiny air bubbles noted between some cells, S/N 5001.  Satisfactory.  Fatigue stress marks were noted on about 20% of the interconnects of each module but no cracks. Markings that possibly were delaminated spots were observed next to some of the stress marks on S/N 4969. Vinyl is more distorted on the back. S/N 4971 laminate shifted further in the frame and the silicone seal at the end is torn away more than before.  Satisfactory.  Satisfactory. No continuity by design.

SUMMARY

Results of Environmental Tests  
of Solar Modules at JPL

Prepared by: R. Lee  
Approved by: *[Signature]*  
Date: 11-1-84  
Rev. *[Signature]*  
Rev. *[Signature]*

GROUP II

Vendor	Module S/Ns	Module Type	Test	Electrical Degrad., %	Comments
ISEC BL V, or 2, LS5P	4976	RA-180-12	M-10K	--	String resistance increased 60% intermittently. Cell string resistance increased from 430 ohms up to 700 ohms intermittently for 224 cycles during the test. 15 additional cracked cells.
	5000		M-10K	--	7 additional cracked cells.
	4976, 5000		Hipot/ Cont'ty	--	Satisfactory. No continuity by design. TESTING COMPLETE.

Revision dates

App'd.

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## FSA MODULE TEST SUMMARY

TEST SPEC 5101-161,162 (100mH/sq cm)

COMMENTS  
 DRAC = Delta PHAX of Control Module  
 I = Identifier: J = JEL, V = Vendor  
 P/FR = Failure Report No.  
 SAT = Tested Satisfactorily  
 SBSTR = Substrate

COEFF = Temp Coefficient  
 DELAM = Delamination  
 DSCN = Discoloration  
 ENCAP = Encapsulation  
 INTCON = Interconnector

ID NUMBER  
 Letters = Mfrer/Block/Use  
 Number = Vendor Serial No.

TLST-DURATION  
 HF = Humidity Freeze-Cycles  
 HS = Hot Spot-Cycles  
 HL = Hail-Size/Inches  
 HI = Mech Integrity-Cycles  
 S/A = Mounted in Subarray  
 T = Temperature-Cycles

DELTA PCT = Difference Percent  
 FF = Fill Factor, FF/isc X Voc  
 FLASH DATE = Date of Elec Test

ELECTRICAL  
 RH = Power Max, 25 Deg C Curve  
 VOC = Open Ckt Voltage, 25 Deg C, V  
 VMP = Voltage at RH, V

PROCUREMENT  
 BLOCK V 754177

RATINGS  
 NOT RATED

STATUS AS OF  
 11/01/84

ID NUMBER LINE TEST DURATION REMARKS

ID NUMBER LINE TEST DURATION REMARKS

LS5P 1 REMARKS

LS5P-4969 1 RCVG 181.84 03/02/84 13.290 19.08 12.020 15.13 .72 8 CELLS CRACKED. BASE.  
 LS5P-4969 2 HIPOT 03/30/84 SATISFACTORY.  
 LS5P-4969 3 CONT'Y 03/30/84 NO CONT'Y BY DESIGN.  
 LS5P-4969 4 T-50 04/11/84 MODULE SLID OUT OF END OF JPL FRAME. SILICONE TORN FROM FRAME  
 LS5P-4969 5 182.57 EDGE 6cm LONG. ALL WHITE VINYL DEFORMED. TEDLAR SHUNK 3cm.  
 LS5P-4969 6 181.53 B/S WHITE VINYL MORE DEFORMED. STRESS MARKS, 20% OF ICs.  
 LS5P-4969 7 HIPOT 09/07/84 SATISFACTORY.  
 LS5P-4969 8 CONT'Y 09/07/84 NO CONT'Y BY DESIGN.

3300

LS5C-4970 1 RCVG 182.52 03/02/84 13.190 19.03 11.950 15.27 .73 5 CELLS CRACKED.  
 LS5C-4970 2 179.43 CONTROL MODULE.  
 LS5C-4970 3 180.47 CONTROL MODULE, BASE.  
 LS5C-4970 4 183.21 +2.1 04/11/84 CONTROL MODULE.  
 LS5C-4970 5 181.01 +0.9 05/07/84 CONTROL MODULE.  
 LS5C-4970 6 181.24 +1.0 06/12/84 CONTROL MODULE.  
 LS5C-4970 7 181.07 +0.9 07/02/84 CONTROL MODULE.  
 LS5C-4970 8 181.95 +1.4 07/18/84 CONTROL MODULE.  
 LS5C-4970 9 182.87 +1.9 08/07/84 CONTROL MODULE.  
 LS5C-4970 10 184.72 +3.0 08/22/84 CONTROL MODULE.  
 LS5C-4970 13 181.45 +1.1 10/09/84 CONTROL MODULE.

LS5P-4971	1	RCVG	179.97		03/02/84	13.130 18.93 11.800 15.25 .72	94 CELLS, CRACKED.	3283
LS5P-4971	2	PRETEST	179.10		03/06/84	BASE.		
LS5P-4971	3	HIPOT			03/30/84	SATISFACTORY.		
LS5P-4971	4	CONT'TY			03/30/84	NO CONT'TY BY DESIGN.		
LS5P-4971	5	T-50	180.21	+0.6	03/30/84	MODULE SLID OUT OF JPL FRAME 4cm. SILICONE TORN FROM FRAME 8".		
LS5P-4971	6				04/11/84	TEDLAR SHRUNK 3mm. ALL WHITE VINYL DEFORMED.		
LS5P-4971	7				08/22/84	MODULE OUT FROM FRAME 5cm. SILICONE TORN 13". B/S WHITE VINYL		
LS5P-4971	8	T-200	181.95	+1.6	08/22/84	MORE DEFORMED. STRESS MARKS, 20% OF ICS.		3303
LS5P-4971	9	HIPOT			09/07/84	SATISFACTORY.		
LS5P-4971	10	CONT'TY			09/07/84	NO CONT'TY BY DESIGN.		
LS5P-4972	1	RCVG	172.62		03/02/84	12.760 18.75 11.380 15.16 .72	19 CELLS CRACKED.	
LS5P-4972	2	PRETEST	170.68		03/06/84	BASE.		
LS5P-4972	3	HIPOT			03/30/84	SATISFACTORY.		
LS5P-4972	4	CONT'TY	168.5.		03/30/84	NO CONT'TY BY DESIGN.		
LS5P-4972	5	T-50				WHITE VINYL DEFORMED ABOUT .6cm in JPL FRAME. WHITE VINYL		
LS5P-4972	6					DISTORTION. SILICONE SEALANT PULLED LOOSE @ 2 CORNERS FOR 7cm,		
LS5P-4972	7					PROBABLY FROM VINYL BENDING & SHRINKAGE (.5 TO 1.0cm).		
LS5P-4972	8	HF-10	165.34	-3.1	07/18/84	SATISFACTORY THIS TEST.		
LS5P-4972	9	M-10K	168.72	-1.2	09/14/84	SATISFACTORY.		
LS5P-4972	10	HIPOT			09/18/84	SATISFACTORY.		
LS5P-4972	11	CONT'TY			09/18/84	NO CONT'TY BY DESIGN.		3221
LS5P-4976	1	RCVG	189.11		03/02/84	13.650 19.25 12.180 15.52 .72	6 CELLS CRACKED.	
LS5P-4976	2	PRETEST	188.44		03/06/84	BASE.		
LS5P-4976	3	HIPOT			05/29/84	SATISFACTORY.		
LS5P-4976	4	CONT'TY			05/29/84	NO CONT'TY BY DESIGN.		
LS5P-4976	5	T-50	185.95	-1.3	06/12/84	WHITE VINYL DISTORTION. SILICONE PULLED LOOSE @ 2 CORNERS, 1 1/4 &		
LS5P-4976	6					15cm. GLASS LAMINATE DROPPED IN FRAME. 2mm TEDLAR SHRINKAGE.		
LS5P-4976	7					SILICONE TEARING & LOOSENING PROPAGATED.		
LS5P-4976	8	HF-10	182.57	-3.1	07/18/84	15 MORE CRK'D CELLS. STRING RES. INCREASED 60% INTERMITTENTLY.		3286
LS5P-4976	9	M-10K	182.75	-3.0	10/09/84	SATISFACTORY.		3292
LS5P-4976	10	HIPOT			10/09/84	NO CONT'TY BY DESIGN.		3318
LS5P-4976	11	CONT'TY			10/09/84			
LS5P-5000	1	RCVG	171.96		03/23/84	12.420 18.90 11.490 14.96 .73	4 CELLS CRACKED.	
LS5P-5000	2	RECHECK	170.33		04/04/84	BASE.		
LS5P-5000	3	PRETEST	173.20		03/38/84	SATISFACTORY.		
LS5P-5000	4	HIPOT			05/29/84	NO CONT'TY BY DESIGN.		
LS5P-5000	5	CONT'TY			05/29/84	WHITE VINYL DISTORTION. SILICONE PULLED LOOSE @ 3 CORNERS, 10,		
LS5P-5000	6	T-50	172.59	-0.4	06/12/84	11 & 30cm. 2mm TEDLAR SHRINKAGE.		3286
LS5P-5000	7					SILICONE TEARING & LOOSENING PROPAGATED.		3292
LS5P-5000	8	HF-10	168.09	-3.0	07/18/84	7 ADDITIONAL CRACKED CELLS.		3317
LS5P-5000	9	M-10K	169.92	-1.9	10/09/84	SATISFACTORY.		
LS5P-5000	10	HIPOT			10/09/84	NO CONT'TY BY DESIGN.		
LS5P-5000	11	CONT'TY			10/09/84			

Item	Part	Test	Value	Date	Notes	Cracks
1	LS5P-5001	RCVG	171.44	03/26/84	BASE. SATISFACTORY. NO CONT'Y BY DESIGN. LAMINATE DROPPED ABOUT .6cm IN JPL FRAME. VINYL END PIECES SHRANK ABOUT .5 TO .7cm. MINUTE AIR BUBBLES BETWEEN CELLS. SATISFACTORY. SATISFACTORY. NO CONT'Y BY DESIGN.	3 CELLS CRACKED.
2	LS5P-5001	RECHECK	171.73	03/26/84		
3	LS5P-5001	PRETEST	169.19	04/04/84		
4	LS5P-5001	HIPOT		04/20/84		
5	LS5P-5001	CONT'Y		04/20/84		
6	LS5P-5001	T-50	170.11	05/07/84		
7	LS5P-5001	HF-10	171.76	07/18/84		
8	LS5P-5001	M-10K	164.41	09/14/84		
9	LS5P-5001	HIPOT		09/14/84		
10	LS5P-5001	HIPOT		09/14/84		
11	LS5P-5001	CONT'Y		09/14/84		
1	LS5P-5082	RCVG	173.16	04/04/84	BASE. SATISFACTORY.	2 CELLS CRACKED.
2	LS5P-5082	PRE-TEST	171.54	07/02/84		
1	LS5P-5083	RCVG	178.45	04/04/84	BASE. HOTSPOT MODULE. SATISFACTORY.	1 CELL CRACKED.
2	LS5P-5083	PRE-TEST	180.36	07/02/84		
3	LS5P-5083	HS-100	179.25	08/07/84		
1	LS5P-5098	RCVG	170.05	04/04/84	BASE.	2 CELLS CRACKED.
2	LS5P-5098	PRE-TEST	170.32	07/02/84		

3220  
3291